Generating Synthetic Images Using Virtual Beamline to Detect Uncommon Flaws on NIF Optics

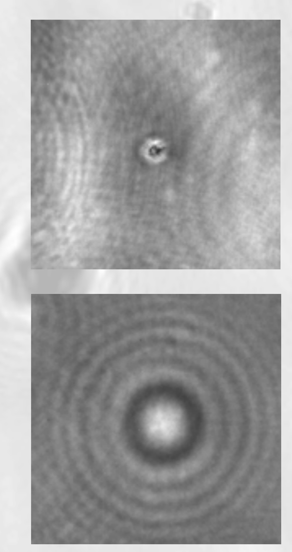
Joshua G. Senecal, Laurie A. Lane

NIF optimizes laser performance and maintains efficient operating costs by repairing and recycling optics as they get damaged by the high energy pulsed laser. An Optics Inspection Analysis system routinely identifies various damage on thousands of optics throughout the facility, helping to inform the optic recycling process. Some remote damage is best found indirectly, by using the signature ("hot spot") it propagates onto an optic closer to the camera. Existing inspection analysis identifies these when the signature matches an expected profile. Here we report progress on a new technique to specifically detect the less common cases, where an atypical remote site produces a signature significantly different than the expected profile. In collaboration with NIF's Laser Modeling group, we are using one of their tools, Virtual Beamline (VBL), to simulate this atypical damage and its resulting signature. This simulated data will be used to supplement existing examples in training a classifier.

Laser Mirror Damage is Detected Indirectly

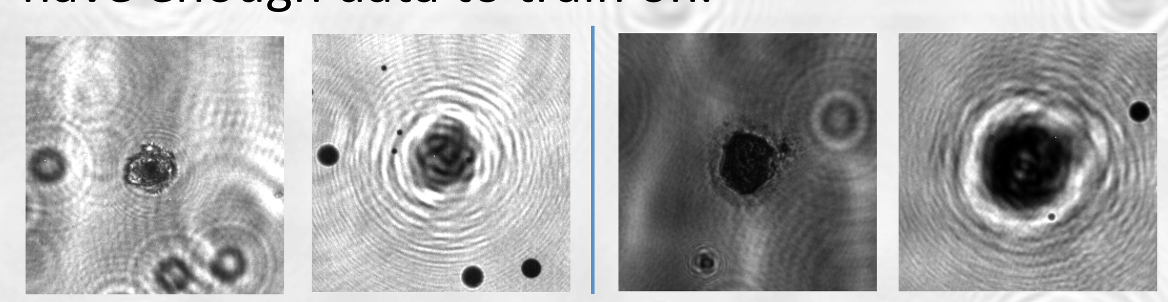
Common "Hot Spots" Are Easily Detected

During a bright-field inspection of the NIF's Final Optics, flaws on the Laser Mirrors (LMs) are detected by the diffraction pattern propagated from the flaw to the Wedge-Focus Lens (WFL). Smaller flaws are identified by their resulting "hot spots", recognized by a trained classifier algorithm.



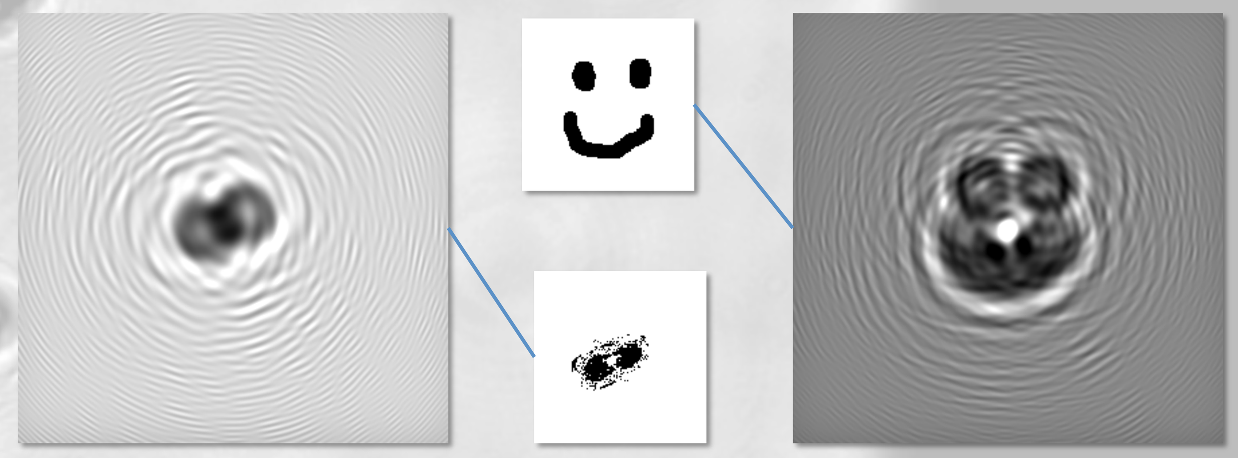
Rare "Dark" Regions Are Not

A rare type of damage produces dark, irregular regions at the WFL. We want to detect these as well, but have very few examples, and so do not have enough data to train on.



Use Virtual Beamline To Simulate Rare Flaws

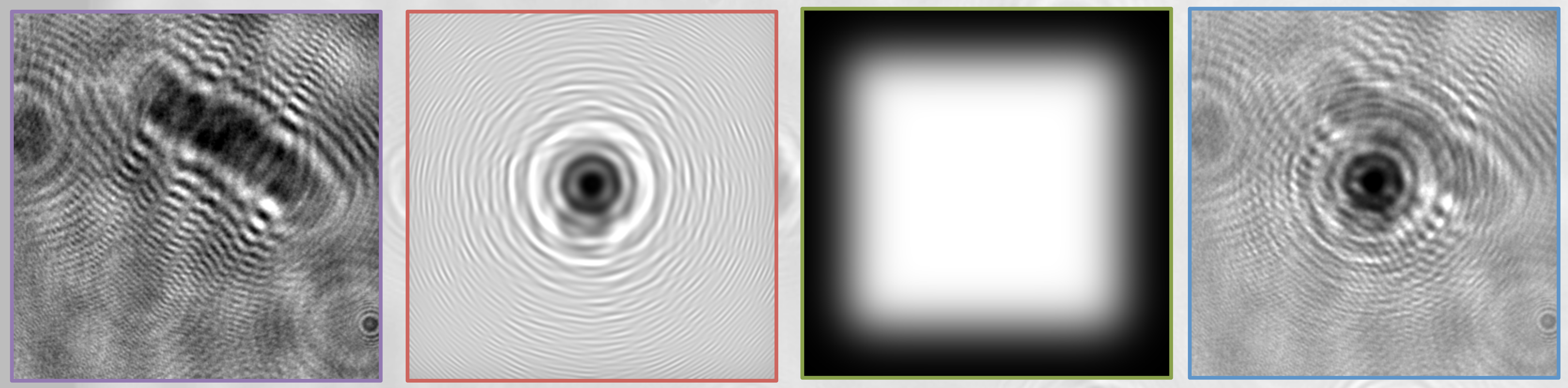
Virtual Beamline (VBL) is a physics code that simulates the interaction of laser light with the optical elements in a beamline. We custom-create LM flaws on binary masks, and use VBL to determine what the resulting diffraction pattern would be at the WFL. This provides us with many more flaw examples than actually exist.



Two flaw masks and their resulting diffraction patterns, as computed by VBL.

Produce Synthetic Data by Blending Actual Imagery With Simulated Flaws

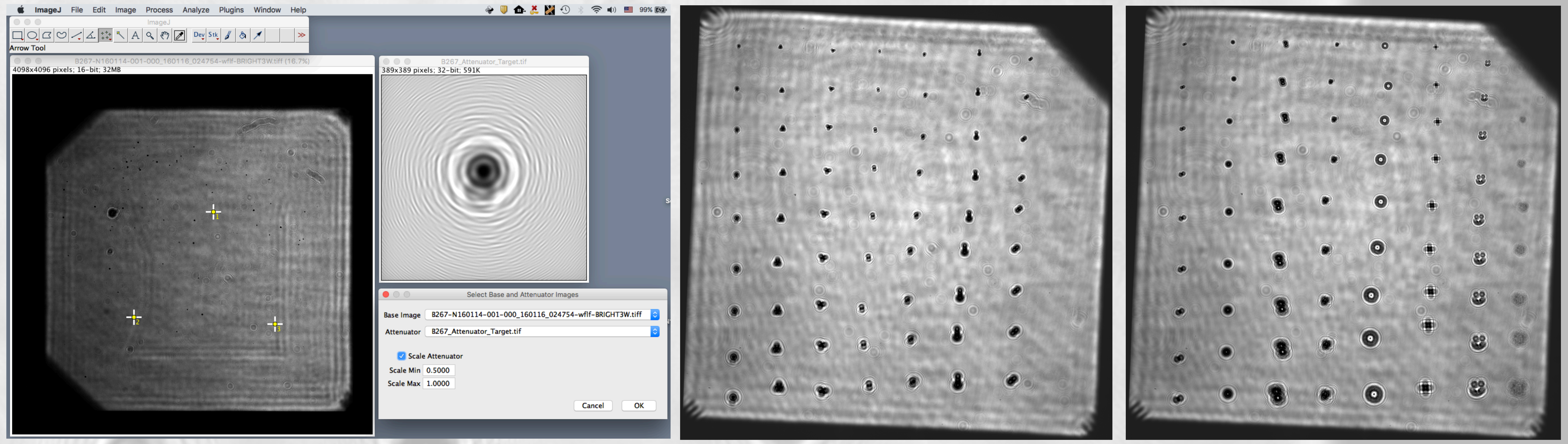
Imagery is Blended, Not Superimposed



We take a source tile ***S***, the VBL-produced flaw evidence ***A*** and a transfer function ***T***. The destination tile ***D*** is created according to

$$D(i) = \big((1.0 - T(i)) \times S(i)\big) + \big(T(i) \times S(i) \times A(i)\big), T(i) \in [0,1]$$

The results are good enough to easily pass visual inspection.



On the left is a screenshot of ImageJ using our custom data-generating plugin. The user has loaded an actual inspection image and a VBL-produced diffraction pattern, and selected three locations in the image where the diffraction pattern is to be placed. On the right are two damage "charts", each with many examples of simulated damage at increasing scales.

Using custom-written plugins for the ImageJ image analysis software we load the simulated flaw diffraction pattern produced by VBL and an actual bright-field inspection image into the ImageJ image analysis software. We add the simulated flaw diffraction pattern at the locations of our choosing, resulting in realistic synthetic data that will be used to train a classifier.

Acknowledgements

We are grateful to Kathleen McCandless for providing access to Virtual Beamline and for her assistance in learning to use it, and to Laura M. Kegelmeyer for her guidance.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
LLNL-POST-689931